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brake is automatic, the fracture of wire or draw-gear ringing bells on engine and caboose, and warning both engineer and conductor that the train has parted, each being then at liberty to apply the brake or not, on his portion of the train, as he may deem best. Owing to the system of circuiting, the brake may be out of order on one car without affecting the rest of the train.

The street-car starter and brake exhibited by Charles T. Brown & Co., Chicago, is an ingenious device for storing the momentum which is destroyed by the usual form of brake, and utilizing it for restarting the car. The motion is not checked by friction, but by the axle, which, through suitable gearing, winds up a spiral spring, the power of which is available to again put the car in motion. The mechanical details appear well worked out, and the car can be run in either direction, and stopped or started on either up or down grades. The heavy pull necessary to start a car is very severe on horses, and this invention would appear to be useful in saving much wear and tear of horse-flesh.

D. H. O'NEALE NEALE.

#### A HEARING OF BIRDS' EARS.<sup>1</sup>—I.

THE 'musical class' of vertebrates enjoy the sense of audition to a high degree. Otherwise birds would cease to sing. They are the only animals besides man whose emotions are habitually aroused, stimulated, and to some extent controlled, by the appreciation of harmonic vibrations of the atmosphere. Most birds express their sexual passions in song, sometimes of the most ravishing quality to human ears, as that of the nightingale, skylark, or blue-bird; and it cannot be supposed that they do not themselves experience the effect of music in an eminent degree of pleasurable mental perturbations. The capability of musical expression resides chiefly in the male sex; the receptive capacity of musical affections appears to be better developed in the female. There is, however, no anatomical difference in their ears. Quickness of ear is extraordinary in some birds, as those of the genus *Mimus* (mocking-birds), which correctly render any notes they may chance to hear, with greater readiness and accuracy than is usually within human compass;

and it may be reasonably doubted whether any other animals than some of the world's greatest musical composers have a higher experience of acoustic possibilities than many birds possess.

Birds' ears have nevertheless a simple anatomical construction, in comparison with those of mammals. The auditory organ is decidedly of the reptilian type; and the arrangement of the parts is, on the whole, quite like that of reptiles. Thus, the cochlea, which in mammals makes from one and a half to five whorls (two and a half in man), is simply a strap-like prolongation from the vestibule, lacking modiolus, lamina spiralis, etc.; the stapes is the only perfected ossiculum auditus; the incus is scarcely recognizable as such, and inseparable from the stapes; the malleus is immense, but outside the ear, furnishing the articulation of the lower jaw, of the zygomatic arch, and of the pterygo-palatal bar; the tympanic bone is represented at most by a few specks of ossification. There is ordinarily no external ear; the whole tympanic cavity is exposed on removal of the membrane, which lies very superficial; the eustachian tubes unite before opening into the pharynx; the petrotic bone, constituting the otocrane or skull of the ear, is less compact and precise than the 'petrous portion' of the mammalian temporal bone, its three bony elements being more distinct; no mastoid portion is recognizable as such, but pneumatic cells of diploë are numberless, and there is direct passage of air from the ear into the hollow of the lower jaw; one of the semicircular canals invades the occipital bone. Other peculiarities will appear as we proceed with our description, in which comparisons will be chiefly made with the human ear.

Most birds have no external ear, in the sense of a fleshy conch or auricle. In bald-headed birds, the meatus externus appears as a roundish orifice at the lower back corner of the head, just above and behind the articulation of the lower jaw. In nearly all birds, the opening is hidden by an overlying packet of feathers, collectively termed the *auriculars* or ear-coverts, on simply raising and reflecting which the meatus is exposed. The auriculars are peculiarly modified feathers, having loosened barbs, doubtless to lessen interference with the passage of sound. In a few birds the border of the meatus develops a slight tegumentary fold, partially occluding the orifice. In various owls, as of the genera *Strix*, *Aluco*, *Asio*, *Nyctala*, but not even throughout this group of birds, an immense tegumentary *operculum*, or ear-cover, is developed, which flap shuts down upon the ear-opening like the lid

<sup>1</sup> Complementary to the article entitled 'The nature of the human temporal bone,' *Journal of otology*, January, 1882. Some portions of that article may perhaps be made clearer by the present one, especially those relating to the parts of a temporal bone as elements of mandibular and hyoidean arches. Figs. 1-4 are borrowed from Prof. W. K. Parker's admirable essay on the development of the fowl's skull, in *Encycl. Brit.*, 9th ed., art. Birds; figs. 5-9 are from Prof. I. Ibsen's beautiful memoir, as cited in the text.

of a box. It hinges upon the anterior border of the meatus, and shuts backward. In some cases the operculum is about as long as the whole skull is deep, and half as wide as long—say, two inches long by an inch wide. On raising such an ear-flap and turning it forward, enormous external bony ear-parts, covered with integument, are displayed. Such expanse of the outer ear results from extension of occipital and squamosal bones into a thin shell bounding the meatus externus above, behind, and below. In the best-marked cases of the kind, especially in *Nyctala*, the parts are exaggerated unsymmetrically on right and left sides, and the whole cranium is distorted. This inflation of the cranium does not affect the inner ear-parts, or the essential organ of hearing. It should be added, in passing, that the so-called 'ears' of various owls, as the 'long-eared' owl, *Asio otus*, and 'short-eared' owl, *Asio accipitrinus*, are simply tufts of feathers on top of the head, over the eyes; these topknots having nothing whatever to do with the ears. Their proper name is plumicorns.

Aside from any such irregularities, the outer ear, or meatus auditorius externus, is a considerable, shallow, roundish depression, in the situation shown in fig. 1, where the reference line 5 crosses it, and where the cross-like object (stapes) marked *st* is seen lying in it. Its ordinary boundaries are, the enormous malleus or quadrate bone, *q*, in front; the expanded rim of the squamosal, *sq*, above; the tympanic wing of the exoccipital (a production of the lateral condylar plate of the occipital, *teo* in fig. 2), behind and below. A bone unknown in human anatomy, the basi-temporal,

which floors the skull from ear to ear, underlying the basi-occipital and basi-sphenoid, also usually contributes to the inferior boundary of the meatus. On removing the quadrate (malleus), the general tympanic depression is seen to be more or less directly continuous with the alisphenoid, and so to conduct into the orbital cavity; the boundary of the meatus

being best marked behind and below by the expansive thin-edged shell of the tympanic wing of the exoccipital. To the brim indicated is attached the membrana tympani; the ear-drum being thus from the configuration of the parts quite superficial, instead of being at the bottom of a long cylindrical tube, as in man. There is, in fact, in birds, no 'meatus auditorius externus,' in the sense of a special bony tube; some slight specks of ossification, when any, about the tympanic membrane itself, being all there is of a tympanic bone ('external auditory process' of human anatomy).

Such shallowness, openness, and superficiality of the parts, brings the cavity of the tympanum or middle ear into full view on removal of the tympanic membrane. On looking into this cavity, as may readily be done in clean, dry skulls of any size,

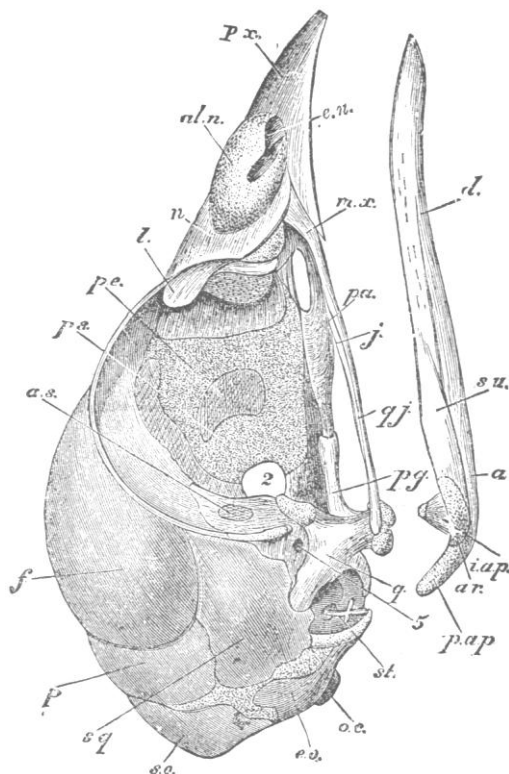


FIG. 1.—Ripe chick's skull in profile,  $\times 3$  diameters. (After Parker.) *px*, premaxillary; *aln*, all-nasal cartilage; *en*, septo-nasal; *n*, nasal bone; *l*, lachrymal; *pe*, perpendicular plate of ethmoid; *ps*, presphenoidal region; *as*, alisphenoid; *f*, frontal; *p*, parietal; *sq*, squamosal; *so*, superoccipital; *eo*, exoccipital; *oc*, occipital condyle; *st*, the cross-like object, the stapes, whose foot fits *fenestra ovalis*; *q*, quadrate; *pg*, pterygoid; *qj*, quadrato-jugal; *j*, jugal; *pa*, palatine; *mz*, maxillary; *2*, optic foramen; *5*, foramen ovale, for inferior divisions of the fifth nerve. In the mandible:—*d*, dentary; *su*, surangular; *a*, angular; *ar*, articular; *iap*, internal angular process; *pap*, posterior angular process.

many objects of interest may be studied without further dissection. We observe in the first place a large (inconstant) number of *pneumatic foramina* leading in various directions, conveying air from the middle ear-passage into the air-cells of bones of the skull, including the lower jaw. The most special of these is a neat gristly or bony air-tube into the lower mandible. The mouth of the eustachian tube is a large orifice at the lower anterior part of the cavity. This tube,

as usual, continues an air-passage to the pharynx, opening at the back of the hard palate by a median orifice in common with its fellow. In sizable skulls, as of a raven, hawk, or eagle, a bristle or even a wooden toothpick readily traverses the conduit which runs between the basisphenoid and the underlying basi-temporal. This whole passageway, from outer ear to tympanic cavity, and thence through eustachian tube to pharynx, represents the persistently patulous part of the first post-oral visceral cleft of the embryo, only occluded by the membrana tympani. Near the eustachian orifice are observed two definite openings. The anterior and superior of these is the fenestra ovalis, fitted, as usual, with the foot of the stapes, as seen in fig. 1, closed by membrane, which further occludes this opening into the *vestibular* cavity. The other is the fenestra rotunda, similarly leading into the *cochlear* cavity. The two are generally close together, separated merely by a bony bridge or bar. The former lies always in the obliterated suture between the proötic and opisthotic elements of the petrosal bone, the latter wholly in the opisthotic; both are thus as in man. Close examination at a point somewhere about the fenestra ovalis will discover a minute foramen, corresponding to the human 'stylo-mastoid foramen' inasmuch as it represents the orifice of exit of the seventh cranial nerve ('portio dura') from the petrosal bone, here in the cavity of the middle ear, there being none such upon the outside of the skull. Thus, in the dry skull of a bird, the hard parts of the tympanic cavity, including the eustachian tube, can readily be inspected from the outside; even the limits of the proötic and opisthotic bones can be determined by the site of the fenestra ovalis, and the ossicula auditus be seen *in situ*. To see these things in the human or any ordinary mammalian ear, requires special preparations, as they lie in a tympanum which is itself at the bottom of a contracted tube. Details of mere size and shape aside, the above general description of the passageways will apply pretty well to any bird, and should suffice for recognition of the parts; though the number and variety of the irregular pneumatic openings (comparable to those of the human mastoid cells) may be puzzling at first sight.

(To be continued.)

#### ON THE KINETIC THEORY OF THE SPECIFIC HEAT OF SOLIDS.

IN a paper entitled 'Kinetic considerations as to the nature of the atomic motions which

probably originate radiations,'<sup>1</sup> the writer has given reasons in support of the hypothesis that different chemical atoms are all composed of the same kind of ultimate atoms, which are in every respect equal and similar. Reasons were also given, tending to show that the vibrations of these ultimate atoms originate luminiferous and thermal radiations. And further, supposing radiations to originate in the vibrations of equal and similar ultimate atoms which are set in vibration by the collision of moving molecules, an attempt was made to prove that two unlike masses of gas which are in thermal equilibrium by radiation will also be so when mixed; i.e., when the equilibrium depends upon the collisions of the molecules rather than upon radiation.

The object of the present paper is to consider the probable physical state of solid bodies, especially as to the amount of energy distributed among the different degrees of freedom possible in such bodies, and to show that the same hypothesis of equal ultimate atoms would cause solids which are in thermal equilibrium by radiation to be also in thermal equilibrium when brought into contact, i.e., when the equilibrium depends upon the collisions of the molecules.

Let us notice, in the first place, what is apparently the mechanical significance of Dulong and Petit's law, which may be stated thus: the amount of heat which must be imparted to a chemical atom of a simple solid body to increase its temperature one degree is approximately the same for all the elements. Neumann has further shown, that, for compound solids, those of similar chemical composition require approximately the same amount of heat per chemical atom, but the amount is less than for simple solids. There are, however, a very few unexplained exceptions to these laws, which are due possibly to uncertainty as to atomic weights.

The mechanical explanation of these experimental laws seems to be contained in the statement, that, in simple solids, cohesion and chemism are one and indistinguishable; or, to express it otherwise, we may say that the molecules of simple solids are monatomic, the cohesion being, of course, much greater in some solids than in others.

That this is a correct conception of the relations of the atoms of a simple solid, is made probable by various facts, among which this may be mentioned,—mercury and cadmium, which are known to be monatomic as gases, as solids fulfil Dulong and Petit's law, and are therefore in the same physico-chemical state

<sup>1</sup> SCIENCE, II. 76.